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Key Lessons from explosions involving hydrogen

Introduction

Hydrogen is a clean alternative to methane, also known as natural gas. It's the most abundant chemical element, estimated to contribute 75% of the mass of the universe. Hydrogen can be produced from a variety of resource, such as natural gas, nuclear power and renewable power such as solar and wind.
Hydrogen has gained attention as a potential clean energy carrier due to its combustion producing only water vapor. Fuel cells use hydrogen to generate electricity by combining it with oxygen from the air. However, challenges like efficient production, storage and transportation hinder widespread adoption. Ongoing research focusses on sustainable methods like electrolysis powered by renewable sources. If harnessed effectively, hydrogen could play a vital role in reducing carbon emissions and advancing a more sustainable energy future.

Case 1 – Power Plant Hydrogen Explosion:

On the 8th of January 2007 a routine gaseous hydrogen (GH_2) delivery resulted in a fatal hydrogen explosion at a power plant in Muskingum, Ohio. Around 9 a.m. on January 8, 2007, personnel maneuvered a large tube trailer into position at the power plant. The trailer held ten cylinders filled with hydrogen at 2500 psi (17.2 MPa) which would be transfilled to two onsite storage vessels. These tanks could hold up to 15,000 cubic feet stored at 2000 psi, equating to approximately 35 kg of hydrogen. The delivery was a routine part of daily operations at the plant, where the hydrogen would be used to cool its generators. Unfortunately, what happened that day was anything but routine. After a rupture disk failed, hydrogen lost containment in the vent piping and rapidly leaked into the air under an overhead awning. Soon after, the combustible mixture in the awning ignited. The explosion resulted in the death of the delivery truck driver, who was killed as he ran back to his vehicle to turn off the hydrogen. Ten nearby plant personnel were also injured in the event, and the energetic explosion tore apart multiple structures at the plant.

Key Findings:

This event began with the premature failure of a rupture disk on the onsite storage tank. This failure, in and of itself, should not have led to the explosion. Instead, hydrogen should have escaped through a properly designed vent system and harmlessly dissipated into the environment above the awning. Instead, the pressurized gas caused the vent system to fail, allowing hydrogen to escape. Hydrogen gas then accumulated under an improperly designed overhead weather awning before igniting. The investigation team could estimated the amount of hydrogen that accumulated before ignition to be 17.7kg. Additional points are the incorrectly sized ruptured disc, no management of change for disc maintenance, indications of corrosion on the disc, hydrogen piping in disrepair, improper hydrogen piping design, weather awning not designed for hydrogen ventilation, blast origin was under the awning and failure to learn from past incidents.

Case 2 – Hydrogen compressor explosion during maintenance.

On 15th of January 2016 a fire and explosion occurred within a gas compressor building at Long Lake, Alberta, Canada. Two fatalities occurred in this incident, one was declared deceased at the scene with the second worker passed away in hospital on the 25th of January 2016. The hydrogen compressor building consisted of two identical compressors with two stages, low pressure and high pressure. The first stage cylinders were located on the south side of the compressor with the second stage located on the north side at height. After receiving the permit to work the permit holder (maintenance team) and process operator carried out a job walk through with the permit holder then meeting his other colleagues in the workshop where they obtained all the tools and the 8 valves that required changing, a total of 3 maintenance workers assigned to the task, workers 1, 2 and 3. From the 11th of January through to the 14th the same team was carrying out the work. As the original team had been asked to investigate oil carry over in the first stage it prolonged the valve replacement work from the scheduled finish of the 14th. The team was asked to work overtime on the 15th to complete the job with worker 1 and 2 accepting. A 4th maintenance worker had to join the team who had never worked within the hydrogen compressor building and there was also a stand in supervisor in place this day. The new team suggested the oil is likely in the second stage of the compressor and agreed to check here. Having replaced all 8 valves and with the work close to completion the team debated on having a coffee break imminently and then drain off excess oil or drain excess oil and finish early for the day. The team voted to drain off the oil first. As worker 2 was exiting the hydrogen compressor building to obtain step ladders they observed worker 1 climbed onto a metal box to reach the cylinder drain point on the second stage of the compressor. Shortly after worker 2 exited the hydrogen compressor building they realised there had been an explosion and smoke was coming from the building with worker 1 and 4 still inside.

Key findings:

Lack of competent supervision, no jobsite walk through for worker 4 and the new supervisor, failure in the permit due to deviation of work. No line break tag register in place.

The ISC believes that leadership across six key functional elements is vital to achieve good process safety outcomes. These elements are:

- systems & procedures
- engineering & design
- assurance
- knowledge & competence
- human factors
  - culture

In the *What can I do* section below you can see how each of these elements plays a part.

What can I do?	
Management	
	• Ensure that safe work systems, such as permit to work specify what work is to be carried out.
	• Ensure flange break tags are in place with suitable recording document.
	• Ensure that personnel are adequately trained, in this case with the use of hydrogen.
	• Ensure that changes to scope are adequately assessed and approved prior to any work taking place.
	• Ensure at all required personnel are adequately trained and competent in the permit to work systems.
	• Ensure all staff are competent for the role including those required to stand up for vacant team members.
	• Have in place an effective Management of Change (MOC) process to adequately record changes from normal operations.
	• Ensure risk assessments are reviewed and updated at adequate time intervals to reflect current conditions.
	• Ensure there is a rigorous inspection programme in place with recommendations followed to potentially limit the impact of corrosion.
Process Engineer/Supervisor	
	• Make sure to follow company guidance and operating procedures to protect workers.
	• Perform regular checks of the worksite to ensure controls are in place and working.
	• Design vent stacks to withstand the pressure and thrust forces associated with a release.
	• Ensure that all scope changes are adequately risk assessed and documented. Any changes must be reviewed to ensure the conditions are suitable for the work to be performed.
	• Ensure plant is designed to allow for automatic emergency shut down should an incident occur.
	• When issuing a permit to work, ensure at all hazards specific to the task are identified and that controls are implemented to manage these hazards ensuring those involved are familiar with the hazards and controls.
	• Ensure all isolations fully documented and perform a line walk to verify all isolations are correct and tested. Line break tags to be in place where required.
	• Have daily or shift briefs to ensure site teams are aware of ongoing work scopes and encourage auditing of work scopes taking place, inclusive of staff and contractors onsite.
Operator	
	• Ensure all plant is safely isolated as required by permit to work systems – perform daily or shift checks.
	• Use good housekeeping and maintenance practices.
	• Perform regular plant checks on all work to ensure it is being performed as required and following the permit to work controls. Audit if required.
	• Carry out pre and post shift worksite inspections/handovers with maintenance/contractors on the work completed to ensure handovers are accurately up to date.
	• Stop the job and report any deviation from the permit to work system including additional members of the work party.
	• Ensure sufficient handover's are in use, documenting all activities.